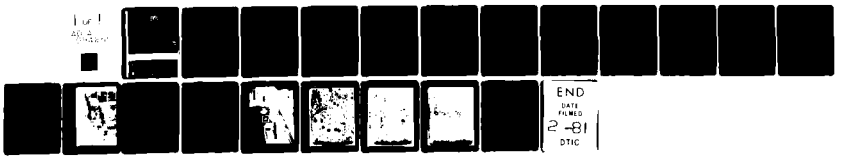
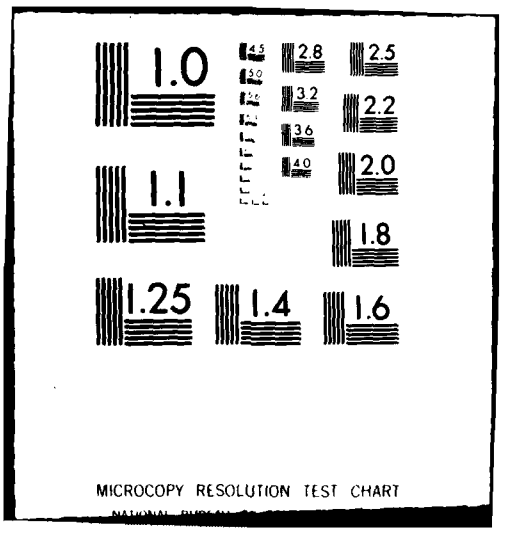
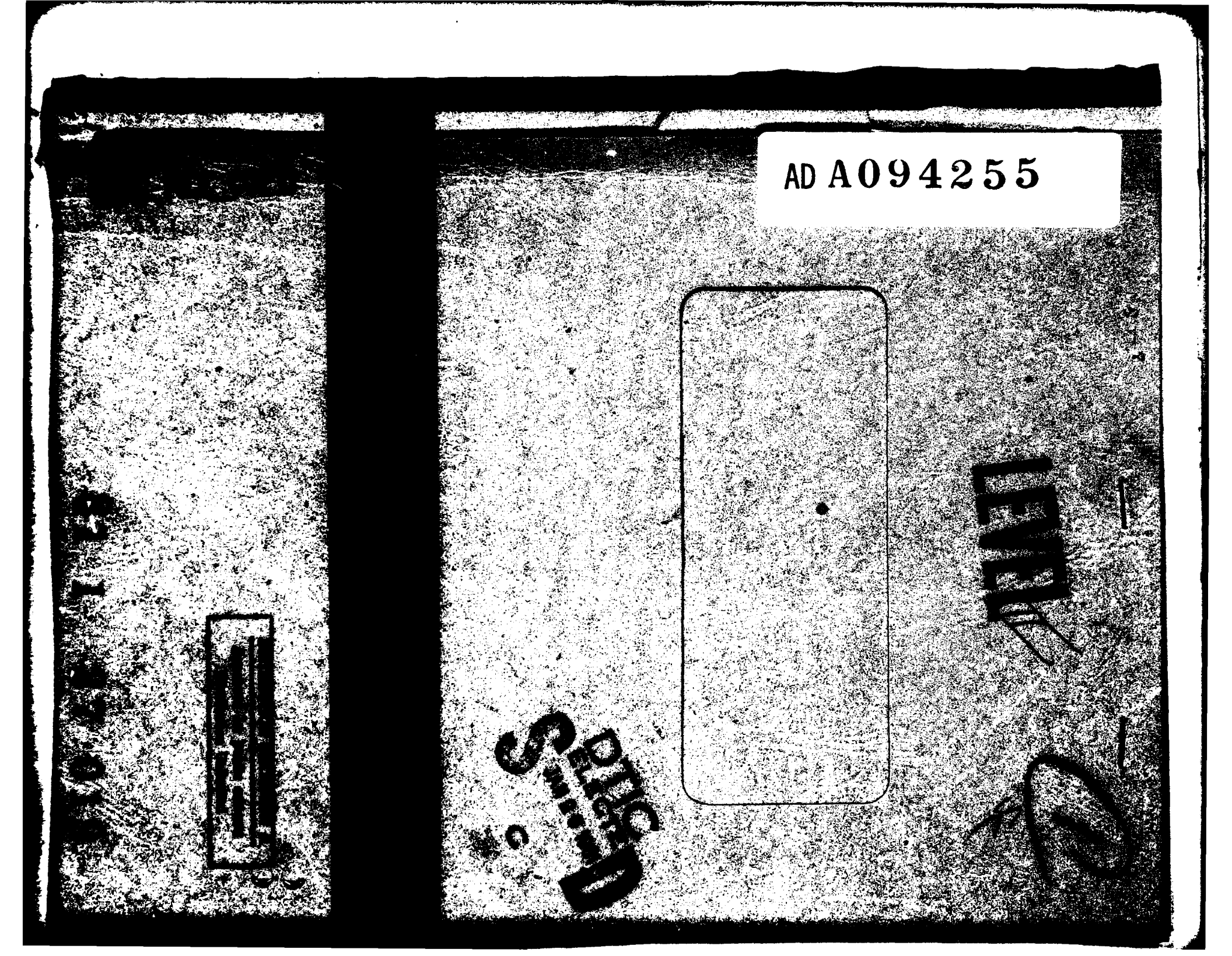
AD-A094 255 CALIFORNIA INST OF TECH PASADENA F/G 14/5
CONSTRUCTION AND CALIBRATION OF AN HOLOGRAPHIC CAMERA DESIGNED --ETC(U)
OCT 79 J KATZ N00014-75-C-0378
UNCLASSIFIED ENG-183-4 NL



END
DATE FILMED
2-81
DTIC


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
MICROCOPY RESOLUTION TEST CHART



CONSTRUCTION AND CALIBRATION OF AN HOLOGRAPHIC CAMERA DESIGNED FOR MICRO BUBBLES OBSERVATION IN CAVITATION RESEARCH.

by

Joseph Katz

This work was supported by Naval Sea Systems Command General Hydromechanics Research Program administered by the David Taylor Naval Research and Development Center under Contract No. N00014-75-C-0138.

Approved for public release; distribution unlimited.

Report No. Eng.-183-4
October 1979

Approved by:
A. J. Acosta

INTRODUCTION

Applying holography as a technique of measuring the size distribution of micro bubbles and particles in liquids brings up the possibility of direct observation of micro objects, and thus knowing their exact shape and size. The present technical note deals with the design of a holocamera, and its calibration.

Holography involves creation of a three dimensional image of a sample volume. Unlike regular photographic records, a hologram contains information, not only of intensities of various objects scattering light into a photographic emulsion, but also the phase difference, between the light coming from an object, and a reference wave. The phase information stored on a film, in form of interference pattern makes it possible, with the help of proper technique, to reconstruct an image of the original sample volume, and to observe it in different magnifications.

In the present system, a ruby laser is used for producing the coherent, linearly polarized light source (0.6943 μm - wavelength) for the hologram recording, and a CW He - Ne laser (0.6328 μm - wavelength) is used as a light source for the reconstruction process. More detailed description of the instrumentation will be given later.

In order to ensure that what we observe on the reconstructed image is a real reproduction of the original sample volume, it is necessary to produce holograms of known objects, and to observe the results obtained. By taking holograms of three sample volumes, containing polystyrene particles of known size - 10μ, 19μ and 50μ; one can calibrate the magnification of the reconstructed image, and can verify that the observed results is an actual image of a photographed sample volume. The present

technical note presents the results of such calibration.

The method used is a Lensless Fraunhofer Holography. It is limited to in line holograms formed in the far field of a subject, allowing observation of one image without confusion from the other.

It involves illumination of a subject with plane coherent light, positioning the photographic recording material in a far-field distance from the object. If the object is small enough, the scattered light from it approaches a point source, and thus, while recording, the result becomes similar to hologram formation of a point source with a plane reference wave. By reconstructing an in line hologram, one produces two images of the original object – a real one and a virtual one. They lie symmetrically to hologram plane on the same axis. The far-field requirement in Fraunhofer Holograms ensures that the "point-source", that appears in the virtual image will produce only a weak uniform background in the real image plane, of the same "point-source". More detailed analysis can be found in Ref. 2, Chapters 2 and 8.

Use of solid state laser–like the ruby laser, is essential in recording of a hologram of a moving object, since it supplies enough intensity needed for a very short time exposure of the film.

METHOD AND INSTRUMENTATION

The application of holography for observing flow characteristics and especially measuring particles and bubbles distribution in water consists of two processes:

The first process involves illumination of a sample volume by a beam of collimated, coherent, quasi-monochromatic light, causing

interference between a coherent background and a particle-diffracted radiation. As long as the particle size is small relative to the main beam dimension, and to the distance between the particle and the holographic film location, the Fraunhofer Holographic technique can be used. The beam is not separated to a reference and subject wave, but instead, only one beam illuminates the sample volume. Part of the light is diffracted by the objects, and most of the beam (undiffracted part) becomes the reference wave. The result of interference between the diffracted and undiffracted light is recorded on a high resolution photographic film, placed in the other side of the sample volume.

In the second process, the photographic record is illuminated by another collimated, coherent light source, producing a three dimensional image of the original volume. By using a "TV" vidicon and monitor one can, with the help of magnifying equipment, focus on any cross section of the reconstructed image field, and observe the result on the "TV" monitor's screen.

The light source of the holocamera is a pulsed ruby laser. A three inch long and quarter inch diameter cylindrical ruby rod is excited by a helical xenon flashlamp, both cooled by a one gpm stream of deionized water. The ruby is located in a 22 inch long optical cavity created by two flat mirrors. The back mirror is a 100 percent reflecting dielectric surface, and the front one is a saphire etalen (60 percent reflectivity), which plays a role in longitudinal mode control of the laser. The cavity is "Q switched" by a KD*P cylindrical ring electrode pockel's cell and a Calcite Glan laser polarizer. Two iris apertures located inside the cavity control the transverse modes of the laser's output.

When the flashlamp is fired approximately 1000 joules, stored in loaded capacitors, discharge through the lamp. The flash is initiated by a high voltage pulse passing through a series injection trigger transformer, which ionize the gas in the lamp and supply the activation voltage for the lamp to discharge.

A highly reflecting cylindrical surface which covers the lamp, reflects back any light emitted to the region outside of the lamp interior, where the ruby is located.

If the cavity is opened (Pockel's cell is not operated) the light emitted by the ruby, is reflected by the flat mirrors back into the rod, and together with the light added from the flashlamp "excite" the ruby to a stage that it emits a giant pulse through the front mirror.

Since the amount of energy supplied, and the duration of the flashlamp operation is enough to emit several pulses, the cavity is "Q switched" as follows. A sufficient voltage is supplied to the $KD^{*}P$ crystal (1.8 KV), to rotate the polarization of incoming light by quarter wavelength. The light is emitted by the ruby and passes through an adjusted Glan Polarizer. While passing through the Pockel's cell, the polarization angle of the incoming beam is rotated by a $\frac{1}{4}\lambda$, and then, after being reflected by the mirror, it returns to the cell. The second passage through the cell causes another rotation of the polarization angle by $\frac{1}{4}\lambda$. As a result, the wave is rotated by $\frac{1}{2}\lambda$, and is deflected by the Glan polarizer outside of the cavity.

The voltage on the Pockel's cell is dropped to zero for a very short time, opening the cavity for light oscillations, and thus for lasing. If the time is adjusted to be sufficient for only one pulse output, one can

get a single ruby laser pulse, whose duration is 20-50 nanoseconds. By opening the cavity more than once, it is possible to produce two pulses (or more), and thus to apply the laser for interferometry.

The control and power supply unit of the Pockel's cell is connected to the main power source. The time delay between flashlamp operation and cavity opening can be adjusted in order to activate the laser in an optimum period during the lamp operation.

The ruby rod and the flashlamp are located in a sealed box, filled with running deionized water (approximately one gpm). After entering the box, the water is injected through six orifices ($\frac{1}{8}$ inch diameter), between the ruby rod and the flashlamp, parallel to the rod's axis, to produce uniform cooling. Before passing through the laser, the water is pumped from a small storage tank, and passes through filters and a deionizer. A conductivity meter, located before the entrance of the laser head displays the water quality before use. To prevent any scale deposit on the ruby's surface, and on the flashlamp, the water is recirculated through the deionizer several times to provide resistivity of at least 18 MΩ cm (much less than 0.1 ppm of any contamination). Brass coils, placed inside the storage tank, in which tap water flows, cool the water after coming back from the laser. A schematic description of the cooling water system is given in Fig. 3.

The laser cavity is very sensitive to alignment. For this reason, each component is mounted on mounts, that provide the possibility of very delicate angle and position adjustment. The alignment is made with the help of an auto collimator and a 0.5 m Watt CW He-Ne laser.

After being emitted from the cavity, the light passes through a beam splitter, from which, approximately four percent of the light is directed towards a PIN diode for examination on an oscilloscope screen. The rest of the beam enters a beam expander – a microscope objective, passes through a spatial filter – a five microns pin hole, located in the focal plane of a 2.5 inch diameter collimating lens. After being collimated the wave illuminates the sample volume, after which the recording film is placed. The recording material is a 70 mm Agfa Gevaert 10E75 photographic film. A schematic description of the holocamera is given in Fig. 1, and is photographed in Fig. 2.

After developing the film, the hologram is mounted on the reconstruction system. It consists of a five m Watt CW He-Ne laser, as an illumination source. The beam is expanded by an objective, filtered by a pinhole, and collimated by a lens. The collimated beam is transmitted through the hologram, and the diffraction pattern caused by the film transmittance creates a three dimensional image of the original volume. By using a microscope objective, a certain desired cross section of the image is magnified and focused on a TV vidicon. The hologram itself is mounted on a x-y-z vernier carriage, making possible (with the help of scales in three dimensions) to observe any point of the reconstructed image on the monitor. A schematic description of the reconstruction system is given in Fig. 4 and its photograph in Fig. 5.

In the present experiment, whose aim is to calibrate the holocamera, and to ensure that the observed image is an actual reproduction of an original photographed object, the sample volume was the content of a half inch long and $\frac{3}{4}$ inch diameter cylindrical glass bottle. Sample

volumes of Ethanol containing polystyrene particles of known size – 10μ, 19μ and 50μ were photographed by the holocamera, and later reconstructed and displayed on the TV screen. A photographic record of some of the 50μ, 19μ and 10μ particles are shown on Figs. 6, 7 and 8 respectively.

RESULTS

The holograms produced, and reconstructed are magnified 220x, making it possible to observe the 10μ, 19μ and 50μ particles very clearly. Figure 6 is a photograph of the TV screen on which 50μ particles are displayed, and Figs. 7 and 8 are of 19μ and 10μ particles respectively.

It should be noted that since the microscope objective focuses one cross section on the TV vidicon, each displayed image contains also light scattered from unfocused particles, lying in the sample volume, in different sections than the focused one. Due to their size it is much easier to see the effect of the unfocused 50μ particles. By observation of the TV screen it is fairly easy to focus on any cross section of the image, by making the boundary lines of the particle sharp and clear.

The 50μ picture in Fig. 6 contains scaling lines. The distance between two lines is 50μ. They were made with the help of a microscope reticle placed in the reconstruction system, before the holograms were reconstructed. The photograph shown is evidence how well the holocamera succeeds to preserve the original sample volume. The 19μ and 10μ photographs were taken with the same magnification. The pictures shown are of the same size as the TV screen, to provide the reader with the actual images observed.

It should also be noted that by moving the microscope objective in the real image field to regions outside of the glass bottle image, no

sign of any particle, or any object can be seen. This fact eliminates the possibility that some images of non-existing particles will be created by any kind of diffraction pattern-like nonlinear effects in film recording. [See Ref. 2].

CONCLUSION

Both the theoretical analysis of in-line Lensless Fraunhofer holograms and the experimental results prove that the particle size does not change in the transverse dimension while reconstructing an image of a sample volume. Due to the fact that no image of any particle was found outside the boundaries of the bottle, it can be concluded that the system does not create any kind of image that did not exist in the original sample volume.

ACKNOWLEDGMENTS

The author would like to thank Professor A. J. Acosta for his advice and supervision. He would also like to thank Dr. Haskell Shapiro for his part in manufacturing the laser power source and its control system, and Elton Daly for his part in designing and machining the mechanical parts and the mounting systems, together with Joseph Fontana, Richard Eastvedt and David Byrum.

This work was supported by Naval Sea Systems Command General Hydro-mechanics Research Program administered by the David Taylor Naval Research and Development Center under Contract No. N00014-75-C-0378.

REFERENCES

1. W. Koechner, Solid State Laser Engineering, Springer-Verlag, New York, Heidelberg Berlin, 1976.

2. Robert J. Collier, Christoph B. Burkhardt, Lawrence H. Lin, Optical Holography, Academic Press Inc., 1971.

3. Max Born, Emil Wolf, Principles of Optics, Pergamon Press, Fifth Edition, 1975.

4. B. J. Thompson, J.H. Ward, W. Finky, "Application of Hologram Techniques for Particle-size Analysis", Appl. Opt. 6, 519, 1967.

5. E.M. Gates, J. Bacon, "Determination of Cavitation Nuclei Distribution by Holography", J. Ship Research, Vol. 22, No. 1, March 1978, pp. 29-31.

6. J. Katz, "Determination of Solid Nuclei and Bubble Distribution in Water by Holography", CIT Report No. Eng. 183-3, June 1978.

7. E.M. Gates, M.L. Billet, J. Katz, K.K. Ooi, J.W. Holl, A.J. Acosta, "Cavitation Inception and Nuclei Distribution, Joint ARL/CIT Experiments", CIT Report No. E244.1.

FIGURE CAPTIONS

Figure 1. A schematic description of the holocamera.

Figure 2. Photograph of the holocamera. The numbers appearing refer to the different components' numbers appearing in Fig. 1.

Figure 3. A schematic description of the cooling system of the laser.

Figure 4. A schematic description of the reconstruction system.

Figure 5. A photograph of the reconstruction system.

Figure 6. A photograph of the TV screen displaying 50μ particles. The distance between 2 lines of the scale is 50μ. The scaling was made using a microscope reticle placed in the reconstruction system.

Figure 7. A photograph of the TV screen displaying 19μ particles. This picture is taken with the same magnification as Fig. 6.

Figure 8. A photograph of TV screen displaying 10μ particles. The picture is taken with the same magnification as Fig. 6 and 7.

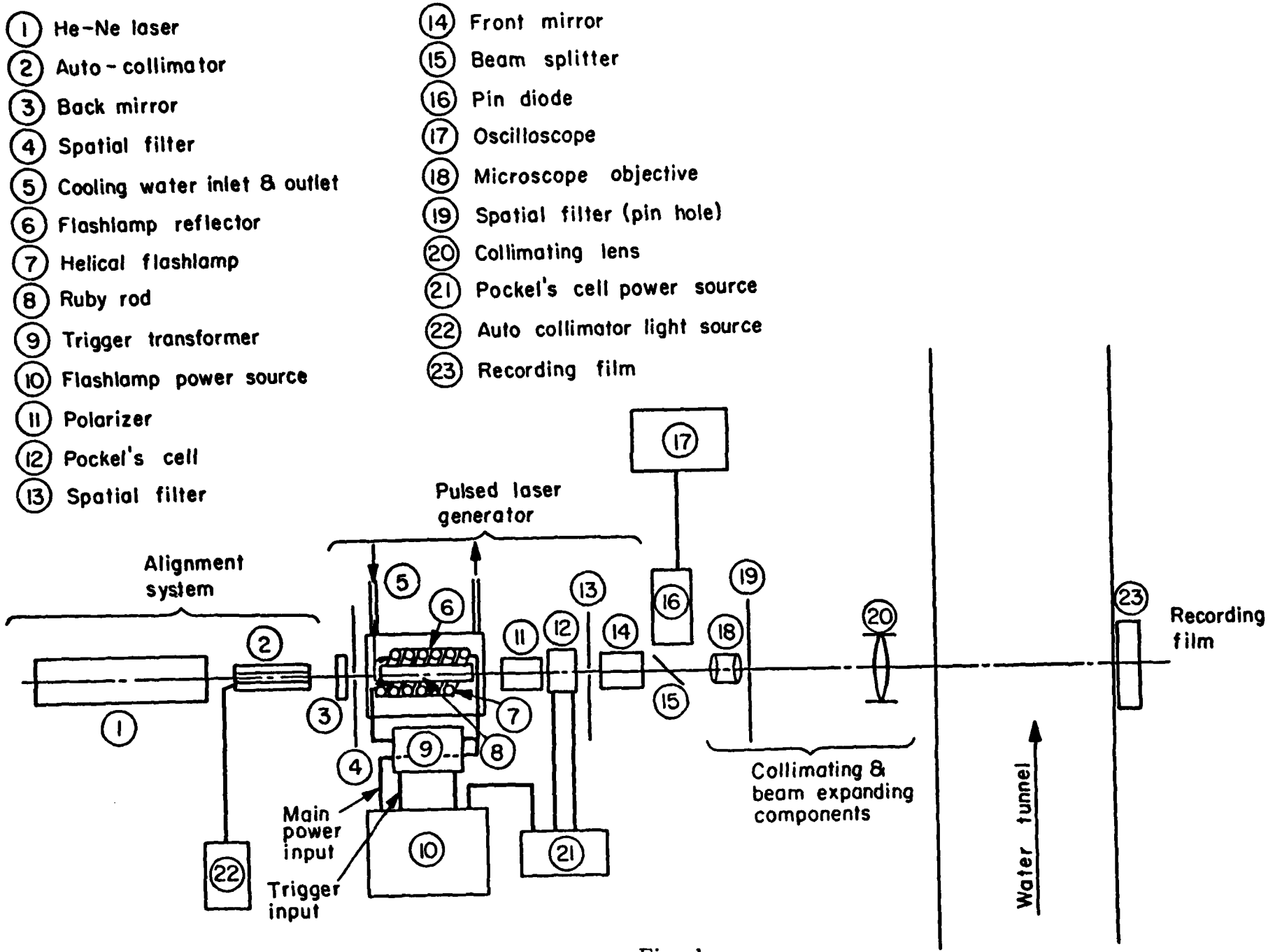

1 He-Ne laser
2 Auto - collimator
3 Back mirror
4 Spatial filter
5 Cooling water inlet & outlet
6 Flashlamp reflector
7 Helical flashlamp
8 Ruby rod
9 Trigger transformer
10 Flashlamp power source
11 Polarizer
12 Pockel's cell
13 Spatial filter
14 Front mirror
15 Beam splitter
16 Pin diode
17 Oscilloscope
18 Microscope objective
19 Spatial filter (pin hole)
20 Collimating lens
21 Pockel's cell power source
22 Auto collimator light source
23 Recording film
Pulsed laser generator
Alignment system
Main power input
Trigger input
Collimating & beam expanding components
Water tunnel
Recording film

Fig. 1

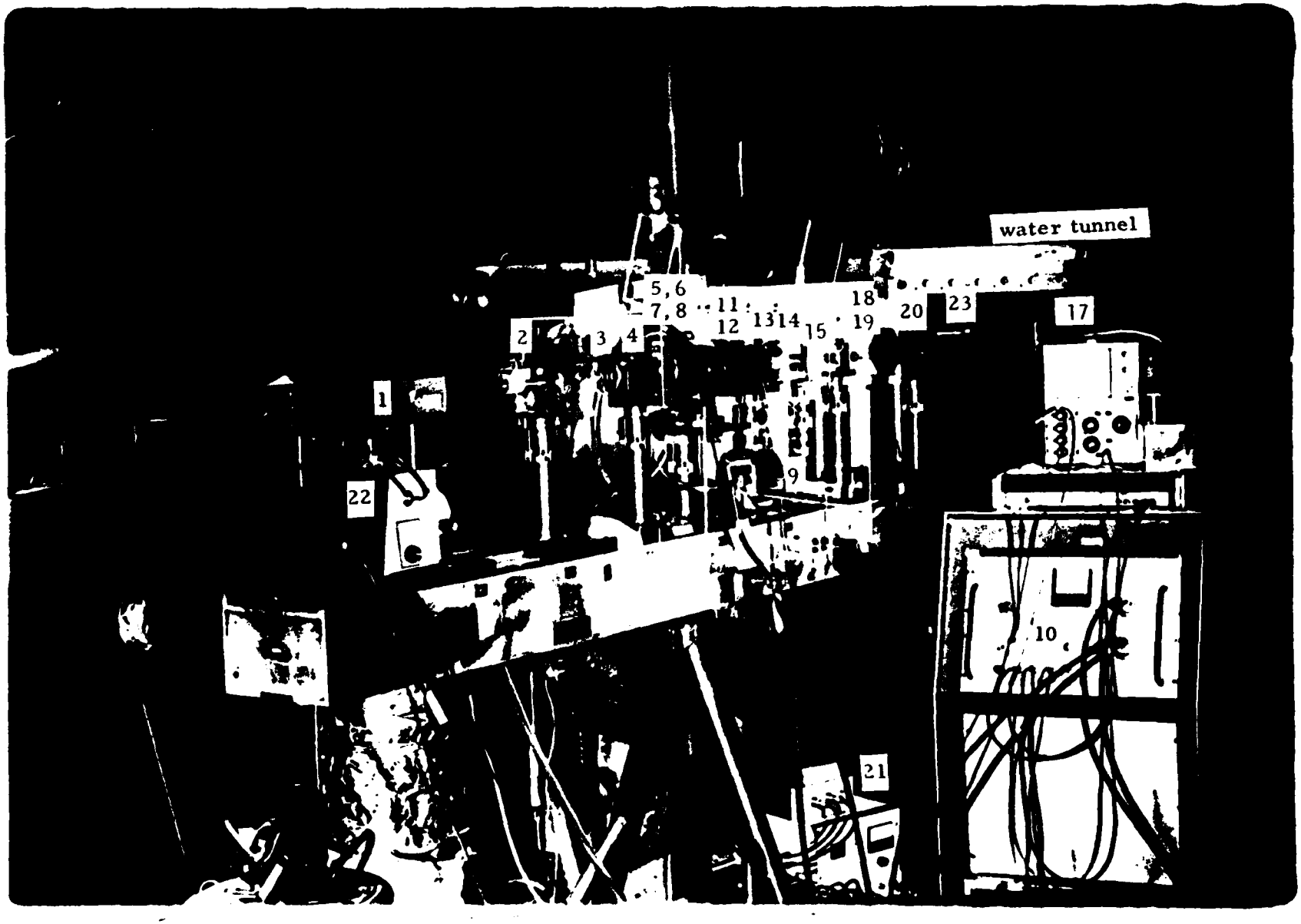


Fig. 2

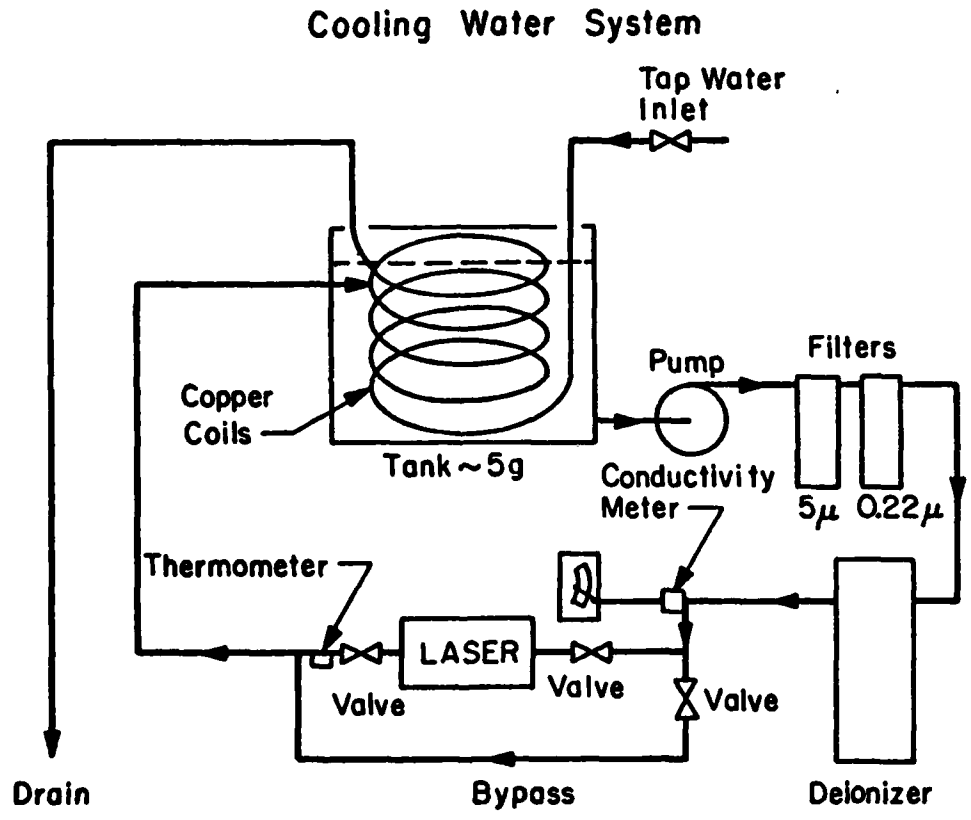

Cooling Water System
Tap Water Inlet
Copper Coils
Tank ~ 5g
Pump
Filters
Conductivity Meter
5μ
0.22μ
Thermometer
LASER
Valve
Valve
Valve
Drain
Bypass
Deionizer

Fig. 3

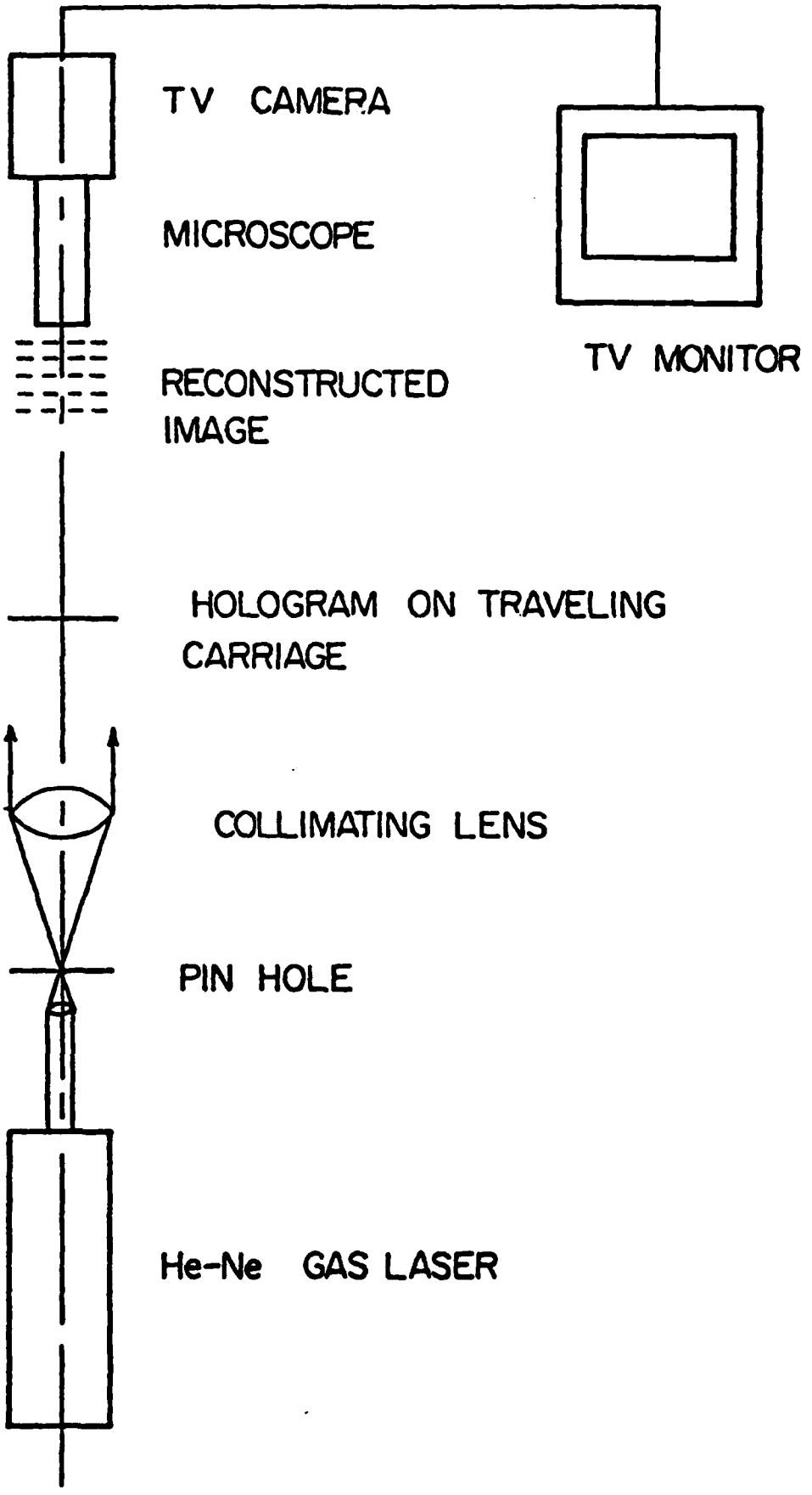


Fig. 4 SCHEMATIC OF READOUT SYSTEM

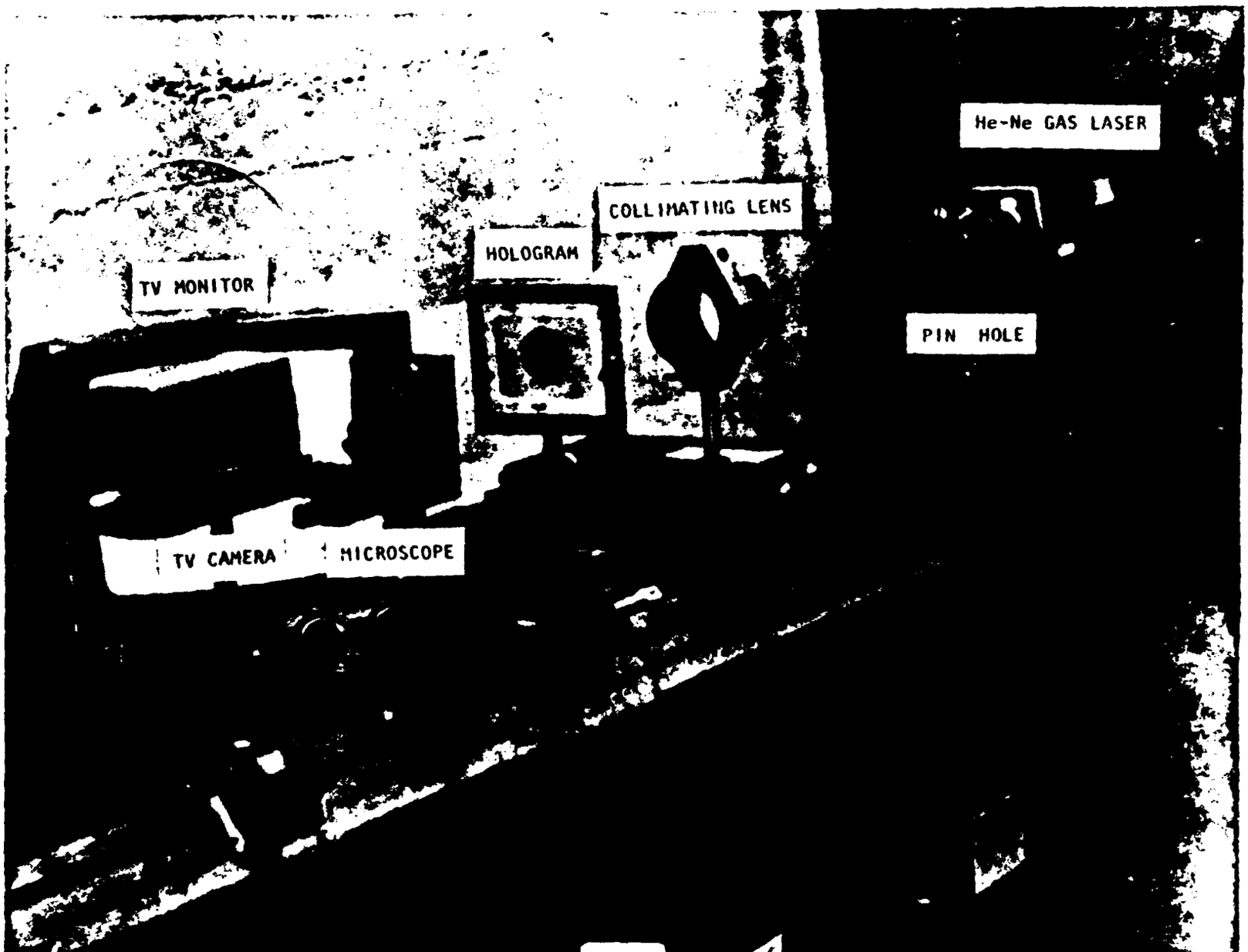

He-Ne GAS LASER
COLLIMATING LENS
HOLOGRAM
TV MONITOR
PIN HOLE
TV CAMERA
MICROSCOPE

Fig. 5

Fig. 6

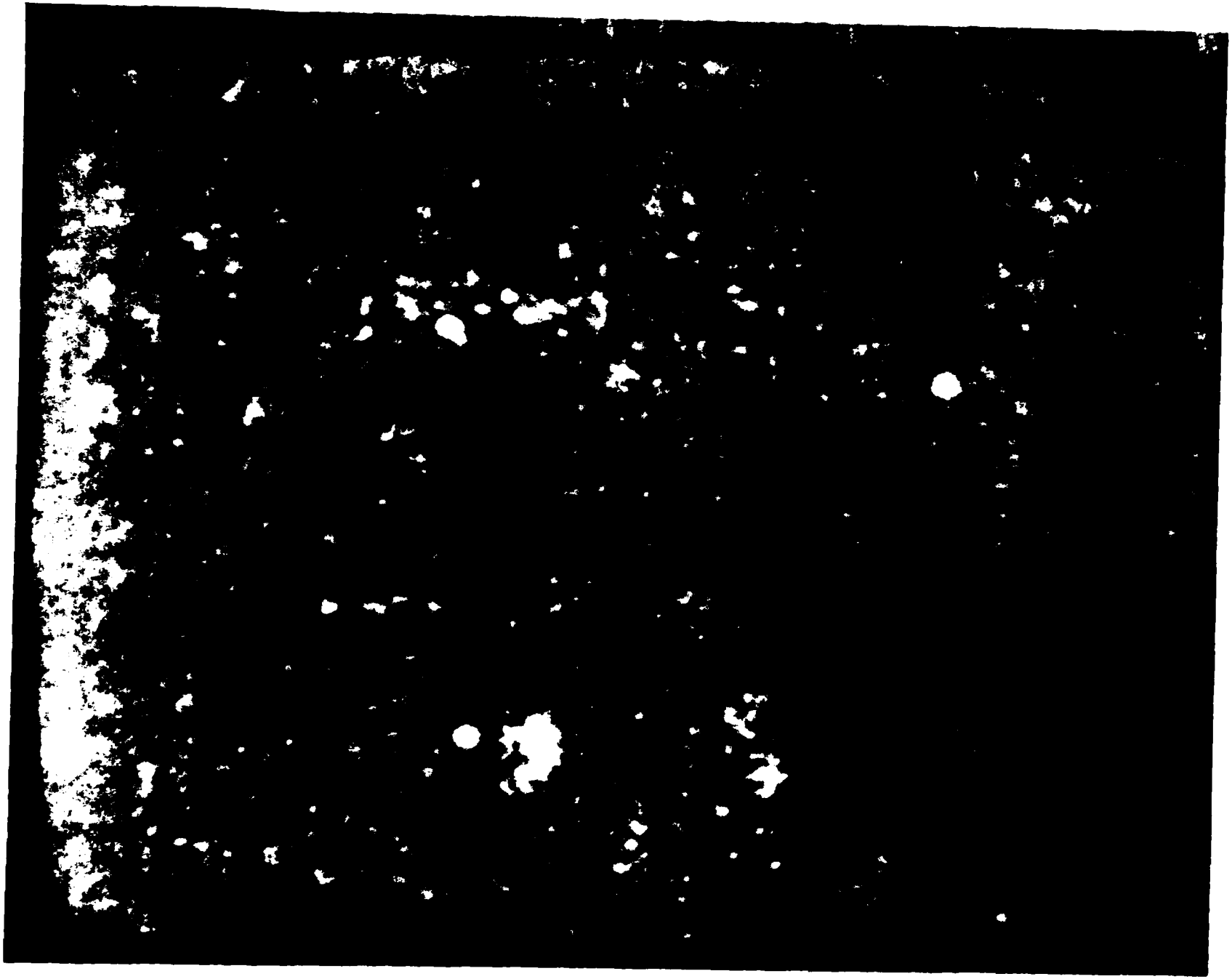


Fig. 7

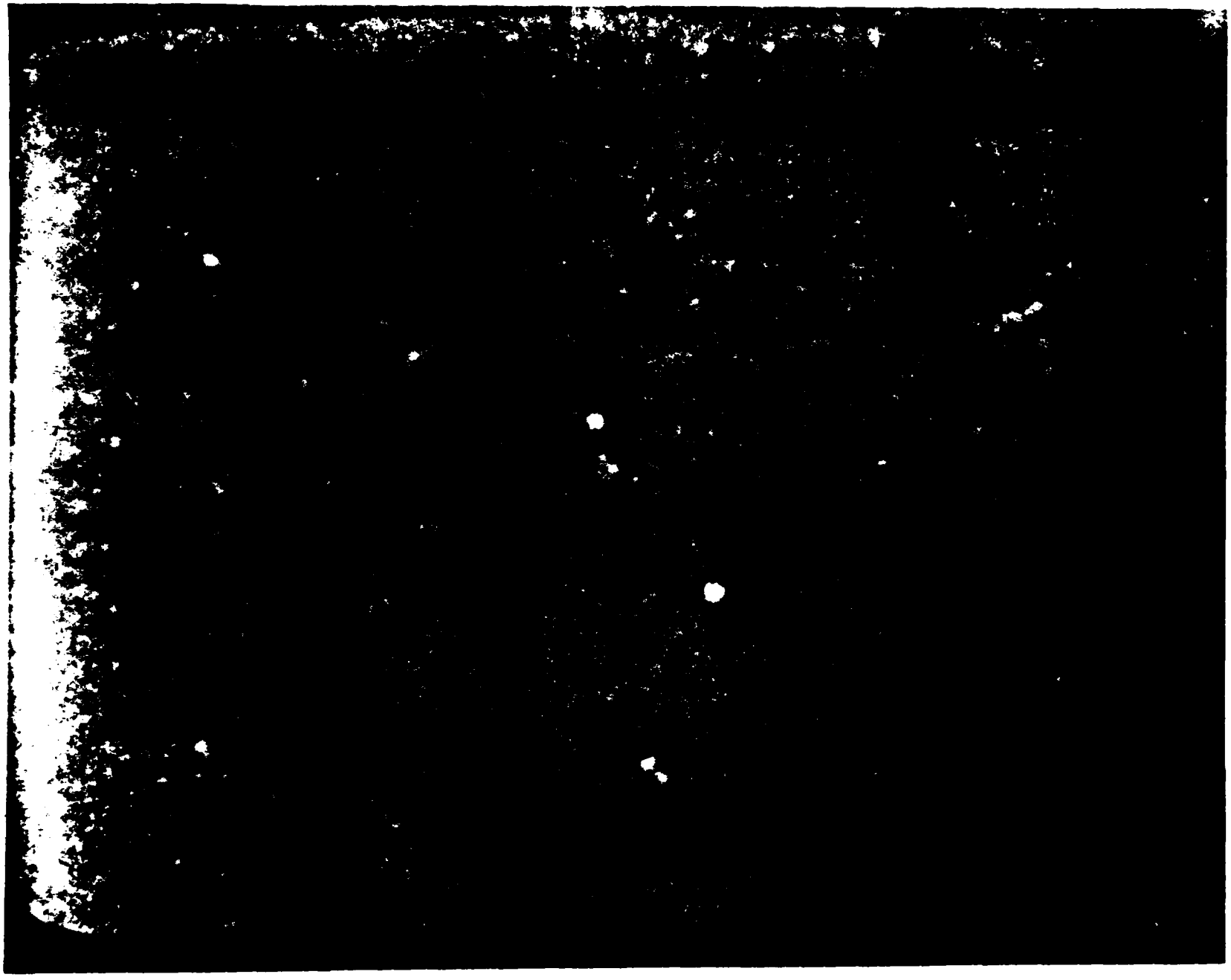


Fig. 8

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Eng. 183-4	2. GOVT ACCESSION NO. AD-A074255	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) CONSTRUCTION AND CALIBRATION OF AN HOLOGRAPH CAMERA DESIGNED FOR MICRO BUBBLES OBSERVATION IN CAVITATION RESEARCH		5. TYPE OF REPORT & PERIOD COVERED Technical 6. PERFORMING ORG. REPORT NUMBER Eng. 183-4
7. AUTHOR(s) Joseph Katz		8. CONTRACT OR GRANT NUMBER(s) N00014-75-C-038
9. PERFORMING ORGANIZATION NAME AND ADDRESS California Institute of Technology Pasadena, California 91125		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS David Taylor Naval Ship Research and Development Center (Code 1505) Bethesda, Maryland 20084		12. REPORT DATE October 1979 13. NUMBER OF PAGES 18
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Office of Naval Research Arlington, Virginia 22217		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Sponsored by Naval Sea Systems Command General Hydrodynamics Research Program administered by the David Taylor Naval Ship Research and Development Center.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Cavitation, Micro bubbles

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102 LF 014 6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)